The role of birds in the natural foci of tick-borne arboviruses in Western Siberia [1]

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In Western Siberia the existence of two arbovirus infections communicated by ixodid ticks has been determined : the Russian spring-summer tick-borne encephalitis (RSSE) and the Omsk hemorrhagic fever (OHF) closely related to it, discovered in 1946-48.

The two viruses belong to the antigenic tick-borne encephalitis complex whose representatives are found in many localities at great distances from one another in Eurasia and North America.

The discovery in India (Work, Trapido and others) of the Kyasanur forest disease, which is etiologically and clinically close to RSSE, showed the possibility of virus exchange between India and Western Siberia, occurring most likely on account of the migration of birds between India and Siberia. Thus, the region of Siberia-India (and more widely South-East Asia) has been selected as a typical area for studying the role of migrating birds in spreading arboviruses on the virus models of tick-borne encephalitis complex. Theoretically, within this region, besides the exchange of arboviruses of the spring-summer tick-borne encephalitis complex, there is the assumption of possible arbovirus transfer of other antigenic groups northward of the Himalayas from South-East Asia and Africa.

Very important in solving these problems can be named the studies on migrating birds in India that have been carried out under the guidance of Dr Sálim Ali.

As we are concerned with viruses communicated by ixodid ticks, the ascertaining of biocoenotic relations of birds with ticks in the foci of corresponding infections will be of foremost interest. This article brings out the basic results of our comparative studies of biocoenotic relations of birds with ticks and viruses in the foci of tick-borne encephalitis and Omsk hemorrhagic fever in Western Siberia.

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The principal transporters of the said viruses are two basic West-Siberian species of ixodid ticks: *Ixodes persulcatus* P. Sch. (taiga foci of tick-borne encephalitis) and *Dermacentor pictus* Herm (forest-steppe foci of OHF). In Western Siberia spontaneous infectivity with both viruses has been repeatedly determined in the said two species of ticks.

The importance of birds in the host range of ticks *Ixodes persulcatus* and *Dermacentor pictus*

Our observations of many years, together with the available data of other authors, have shown that the role of birds in harbouring ticks is quite different for each of the two basic West-Siberian species (see Table 1).

Table 1

Host-range of *I. persulcatus* and *D. pictus* in Western Siberia

	Number of species of vertebrates acting as tick hosts	
	I. persulcatus	*D. pictus*
Amphibia ..	1	1
Reptilia ..	3	2
Aves ..	77	6
Mammalia ..	59	53
Total ..	140	62

The said species of ticks differ basically in that the *I. persulcatus* feeds broadly on birds and mammalia, while *D. pictus* feeds mostly on mammalia (rodents and insectivorae) and where birds, amphibia and reptilia serve only as accidental hosts. In the present instance the question concerns the feeding of larvae and nymphs of ticks, as the imagines of both species feed on large mammalia, principally on cattle.

An idea of the role of different species of birds in harbouring *I. persulcatus* is given in Table 2.

It can therefore be said that the number of bird species acting as tick-carriers, will be the greater the greater the area of forested territory, that is, from 23 species in large taiga areas to two species on the terraces on the flood-lands of taiga rivers, where the vegetation is represented by shrubs and thinned groves. The leading role belongs to *Anthus trivialis*, *Turdus pilaris* and *Emberiza citrinella* which become regularly

TABLE 2

BIRDS ACTING AS CARRIERS OF *I. persulcatus* TICKS IN DIFFERENT AREAS OF TERRITORY WHERE TICK-BORNE ENCEPHALITIS IS ENDEMIC (FOREST-STEPPE ON FOOTHILLS AND HIGHLAND TAIGA OF WESTERN SIBERIA)

Species of birds	Taiga	Pine forest along rivers	Forest-steppe	Terraces on the flood-lands
1. *Tetrao urogallus* L.*	+	—	—	—
2. *Lyrurus tetrix* L.*	—	+	—	—
3. *Tetrastes bonasa* L.**	+	—	—	—
4. *Dryobates major* L.	—	+	—	—
5. *Anthus trivialis* (L.)**	+	+	+	+
6. *Motacilla caspica* (Gmelin)	+	—	—	—
7. *Carpodacus erythrinus* (Pall.)*	+	+	—	—
8. *Fringilla montifringilla* L.*	+	—	—	—
9. *Fringilla coelebs* L.*	—	+	—	—
10. *Pyrrhula pyrrhula* L.*	+	—	—	—
11. *Passer montanus* (L.)	—	+	—	—
12. *Emberiza aureola* Pall.*	+	+	+	+
13. *Emberiza rustica* Pall.	+	—	—	—
14. *Emberiza leucocephala* S. G. Gmelin**	+	+	—	—
15. *Emberiza citrinella* L.**	+	+	+	—
16. *Sitta europaea* L.	+	+	—	—
17. *Parus major* L.	—	+	—	—
18. *Erithacus svecicus* (L.)	—	—	+	—
19. *Luscinia luscinia* L.	+	—	—	—
20. *Luscinia calliope* (Pall.)*	+	+	—	—
21. *Saxicola torquata* (L.)	—	+	—	—
22. *Turdus ruficollis* Pall.**	+	—	—	—
23. *Turdus pilaris* L.**	+	+	+	—
24. *Turdus philomelos* Brehm	+	—	—	—
25. *Turdus iliacus* L.	+	—	—	—
26. *Phoenicurus phoenicurus* (L.)*	+	—	—	—
27. *Prunella montanella* Pall.*	+	—	—	—
28. *Sylvia communis* Lath.	+	—	—	—
29. *Phylloscopus trochilus* (L.)	+	—	—	—
30. *Lanius cristatus* L.	+	+	—	—
31. *Garrulus glandarius* (L.)	+	—	—	—
Total number of species of tick-carriers	24	15	5	2

* Uncommon species of birds regularly infested by ticks.
** Common species of birds regularly infested by ticks.

infested, and are the most numerous on all the mentioned areas, or at least on three of the four observed. A substantial role also belongs to *Emberiza aureola* which, though less numerous, is nevertheless regularly infested in all of the areas. The extent to which various bird species are infested depends on the peculiarity of their food, as well as the average time spent daily on the ground.

The number of bird species taking part in the feeding of ticks *I. persulcatus* varies in different areas, and depends on the general reserve of immature stages on the given territory (Table 3).

TABLE 3

PERCENTAGE OF BIRDS INFESTED BY TICKS; THE RESERVE OF IMMATURE STAGES OF *I. persulcatus*, AND THE NUMBER OF BIRD SPECIES ACTING AS TICK-CARRIERS IN DIFFERENT TYPES OF FOCI

Index		Taiga	Pine forest along rivers	Forest-steppe	Terraces on the flood-lands
Reserve of the immature stages *I. persulcatus* (Total index of feeding in the average per season)		20·8	12·8	10·0	5·0
Number of bird species acting as tick-carriers	(*a*) sporadically infested by ticks	9	6	1	2
	(*b*) regularly infested by ticks	8	5	1	—
	(*c*) mass infestation by ticks	6	4	3	—
	In all	23	15	5	2
Average percentage of birds infested by ticks		46·5	40·0	16·2	1·8

Birds become particularly infested in the years when the number of small mammals is low, and when they serve to fill up the deficiency in hosts (Shilova 1966). This shows the substantial role birds play in keeping up the number of ticks *I. persulcatus*.

Absolutely different relations obtain in areas where *D. pictus* predominates. Birds are infested with ticks of this species at an average of only 0·1-0·9% (forest-steppe of West Siberian lowland). Unitary nymphs of *D. pictus* have been collected from *Tringa ochropus*, *Anthus trivialis*, *Motacilla flava*, *Emberiza citrinella*, *Emberiza schoeniclus* and *Turdus philomelos*. It follows from this that birds may serve only as accidental hosts of *D. pictus*, which nevertheless does not signify their exclusion from the virus circulation (see below).

The fact that *D. pictus* does not parasitize on birds has been repeatedly noted by a number of authors who have worked in Western Siberia, but has not so far received satisfactory explanation.

BIRDS, AS THE FACTOR OF FORMATION OF MIXED IXODID TICK FAUNA AND THE FACTOR OF COMBINING NATURAL FOCI OF VARIOUS INFECTIONS

The retention of virus population on a given territory is ensured by its reproduction during the circulation process within the range of conforming biocoenosis, as well as by viruses brought in with arthropods and vertebrates. Here a certain role must belong to birds, capable of promoting virus exchange between foci not only within limited areas, but over large distances as well (migrating birds). Birds may act as the factor of formation of mixed tick fauna, and of combining natural foci of various tick-borne infections.

In Western Siberia some Altai regions are of special interest, where the tick-borne encephalitis fauna is represented by five species of ticks : *I. persulcatus*, *I. apronophorus*, *Haemaphysalis concinna*, *D. pictus* and *D. silvarum*. *Ixodes persulcatus* and *Haemaphysalis concinna* can be named as the most numerous tick species in the biotopes investigated. These species, in the present case, are epidemiologically significant as being the carriers of tick-borne encephalitis and tick-borne typhus fever (Serdyukova 1956 ; Shaiman *et al.* 1966), and they regularly parasitize on birds (see Table 4).

TABLE 4

SPECIES OF BIRDS INFESTED BY TICKS IN THE INVESTIGATED AREAS OF ALTAI

Bird species	Species and stages of ticks					
	I. persulcatus			*H. concinna*		
	larvae	nymphs	imagines	larvae	nymphs	imagines
1. *Accipiter nisus* L.	+	—	—	—	—	—
2. *Alauda arvensis* L.	—	—	—	+	+	—
3. *Anthus trivialis* L.	+	+	+	+	+	—
4. *Motacilla caspica* (Gmelin)	—	+	—	—	—	—
5. *Turdus pilaris* L.	+	+	+	+	+	—
6. *Turdus philomelos* Brehm	+	—	—	—	—	—
7. *Turdus iliacus* L.	+	—	—	—	—	—
8. *Turdus ruficollis* Pallas	+	—	+	—	—	—
9. *Sylvia communis* Latham	—	+	—	—	—	—
10. *Parus major* L.	—	+	—	—	—	—
11. *Emberiza citrinella* L.	+	+	+	+	+	—
12. *Emberiza leucocephala* S. G. Gmelin	+	+	+	+	—	—
13. *Emberiza spodocephala* Pallas	—	+	—	—	+	—
14. *Coccothraustes coccothraustes* (L.)	—	—	—	+	—	—
15. *Pyrrhula pyrrhula* L.	+	—	—	—	—	—
16. *Carpodacus erythrinus* (Pallas)	+	+	—	—	—	—
17. *Fringilla coelebs* L.	+	+	—	—	—	—
18. *Sturnus vulgaris* L.	—	—	+	+	—	—
19. *Nucifraga caryocatactes* (L.)	+	—	—	—	—	—
In all		17			8	

Ixodes persulcatus has been found on 17 bird species in the immature stage and as imago. *Haemaphysalis concinna* has been found only on eight bird species and exclusively as larvae and nymphs. Hence, *I. persulcatus* attacks birds more readily than *H. concinna*. Table 5 shows the state of infestation of birds and small mammalia by these two tick species in different biotopes.

TABLE 5

COMPARATIVE DATA ON THE INFESTATION OF SMALL MAMMALIA AND BIRDS BY TICKS

(Observations made in Altai)

Animal group and area of observation	Number of animals examined	Ixodid ticks collected (L+N+I)	*I. persulcatus* % of infestation				*H. concinna* % of infestation			
			L	N	I	in general	L	N	I	in general
Small mammalia										
Secondary birch-aspen-pine forests	191	341	41·3	6·8	0	41·3	2·4	0	0	2·4
Foothill forest-steppe	126	146	34·1	2·3	0	34·1	27·7	31·1	0	29·9
Birds										
Secondary birch-aspen-pine forests	157	643	28·6	26·7	16·5	39·1	8·9	17·1	0	26·0
Foothill forest-steppe	33	55	3·0	3·0	0	6·0	18·1	24·2	0	30·3

Nymphs of *H. concinna* in secondary forests have been found only on birds; small mammalia were left practically uninfested. The birds, obviously, become parasitized with this tick beyond the bounds of secondary forests, and, in the present case, in the foothill forest-steppes, where *H. concinna* are much more numerous than under the cover of the forest. The foothill forest-steppes, due to their mixed character of biotopes, concentrate birds that act as hosts for *H. concinna* (*Turdus pilaris*, *Anthus trivialis*, *Emberiza leucocephalos*, *E. citrinella*). The constant daily shifting of certain bird species (search of food for young, daytime location, etc.) from foothill forest-steppes to the secondary forests serves to transfer *H. concinna* into the forest biotopes.

At the same time there occurs the transport of ticks from the secondary forests to the foothill forest-steppes. In this respect it is especially interesting that birds of the sparrow family are parasitized not only by larvae and nymphs of *I. persulcatus*, but by the imago of the latter as well. In connexion with the discovery in Altai of the tick *Ixodes pavlovskyi*, similar to *Ixodes persulcatus* and co-existing with it in the same biotopes, and owing also to the inclination of *I. pavlovskyi* to feed on birds, Filippova & Ushakova (1967) suggested that the imagines of ticks in our collections from birds belong mostly to *I. pavlovskyi*. The leading role of *Ixodes* sp. as carriers in secondary forests belongs to *T. pilaris* (infestation up to 69%), as well as to *E. citrinella* and *E. leucocephalos* (infestation up to 50%).

These observations allow us to consider birds as one of the factors providing the formation of mixed ixodid fauna in the said locality on the boundary between the forest-steppe and the taiga. *I. persulcatus* and *H. concinna* are the vectors of tick-borne encephalitis and Asian tick-borne rickettsiosis, and birds, as it can be seen, play a definite role in forming combined foci of these infections in Western Siberia (Netsky, Shaiman).

According to observations made by H. Hoogstraal *et al.* (1963) the exchange of ixodid ticks by migrating birds is also possible at great distances. In this case the repeated bringing in of even single ticks may be of significance, while its possibility is predetermined by the regular mass migration of birds along evolutionally established routes.

Our observations show that ticks of the local ixodid fauna may take part in irradiating pathogens brought in from a definite spot to adjacent territories. This is, apparently, most probable where the biotope changes and in the presence of ticks that actively attack birds.

The role of birds in the circulation of tick-borne arboviruses without the participation of ixodid ticks

Participation of birds in the circulation of West Siberian tick-borne arboviruses (tick-borne encephalitis and Omsk hemorrhagic fever) is effected not only by the attacks of ixodid ticks, but by other ways in which birds get infected. Thus, in the forest foci of RSSE, *I. persulcatus* regularly feed on birds (21 to 40% of the birds are parasitized by ticks), on the other hand, in forest-steppe foci of OHF *D. pictus*, which is the dominant species there, leaves the birds practically untouched (only 0·1 to 0·9% of the birds are parasitized).

At the same time Matyukhin and Fedorova *et al.* (1966) have shown that in the forest foci of RSSE, as well as the forest-steppe foci of OHF, there occurs wide contact of birds with viruses. The immune layer against viruses of the RSSE complex in forest-steppe foci makes up 22·9%, and in the forest-steppe areas from 13·4 to 22·3%. As a whole, in the forest-steppe foci of OHF out of 606 specimens of birds (77 species) antibodies to viruses of the RSSE complex were found on 87 birds (32 species) (see Table 6). In the latter case the rare instances of ticks attacking birds are, apparently, insufficient to maintain the immune layer on said level.

TABLE 6

BIRDS IN FOREST-STEPPE FOCI OF OHF WITH ANTIBODIES TO VIRUSES OF THE RSSE COMPLEX (MATYUKHIN, FEDOROVA *et al.* 1966)

1. *Anthus novaeseelandiae* Gmelin
2. *Anthus trivialis* (L.)
3. *Acrocephalus agricola* (Jerdon)
4. *Motacilla alba* L.
5. *Motacilla flava* L.
6. *Motacilla citreola* Pallas
7. *Emberiza citrinella* L.
8. *Emberiza schoeniclus* (L.)
9. *Emberiza pallasi* Cabanis
10. *Emberiza leucocephalos* S. G. Gmelin
11. *Emberiza aureola* Pallas
12. *Alauda arvensis* L.
13. *Oenanthe isabellina* (Temminck
14. *Panurus biarmicus* (L.)
15. *Sylvia borin* Boddaert
16. *Saxicola torquata* (L.)
17. *Erithacus svecicus* (L.)
18. *Corvus corone* L.
19. *Anas crecca* L.
20. *Anas querquedula* L.
21. *Anas platyrhynchos* L.
22. *Anas strepera* L.
23. *Anas acuta* L.
24. *Anas penelope* L.
25. *Aythya fuligula* (L.)
26. *Aythya ferina* (L.)
27. *Anser anser* (L.)
28. *Tringa glareola* L.
29. *Phalaropus lobatus* (L.)
30. *Podiceps auritus* L.
31. *Sterna hirundo* L.
32. *Larus canus* L.

In the present case, mosquitoes are the most probable vectors for immunizing birds with virus. Positive results have been achieved in the virologic studies of mosquitoes carried out on a territory endemic with OHF and characterized by an abundance of lakes, as well as a wide zone of reed growth and marshes serving for the mass propagation of mosquitoes and the concentration of migrant waterfowl: eight strains of virus, identified as the virus of OHF, have been isolated from the mosquitoes *Mansonia richardii* Fic., *Aedes flavescens* and *A. excrucians*

(Netsky *et al.* 1966). Subsequently the virus of OHF has been repeatedly isolated from mosquitoes during two or three seasons in two different localities separated by a distance of 300-400 kilometres, but with similar landscape. It was also shown experimentally that mosquitoes (*M. richardii*) are capable of being infected with the virus of OHF on an infected white mouse, and of communicating the virus by stinging a healthy mouse (Volynets & Bogdanov 1971).

Mosquitoes in the forest-steppe foci of OHF can, therefore, be considered as the probable vector of virus to birds, since the role of ixodid ticks in the present case is excluded.

Conclusion

In West-Siberian foci of tick-borne encephalitis and Omsk hemorrhagic fever wide participation of birds has been established in the circulation of definite viruses. Involvement of birds in the circulation of viruses in the taiga and adjacent areas is connected with the regular feeding of ticks *Ixodes persulcatus* and *Haemaphysalis concinna* (latter in Altai) on birds. In the forest-steppes of Western Siberia birds are drawn into the circulation of these viruses without the ixodid ticks taking part, as the tick *Dermacentor pictus* practically does not attack birds. Mosquitoes are considered as the most probable carriers of viruses among birds.

The movement of birds assists in the formation of mixed ixodid fauna and of combined foci of infections connected with different species of ticks, which occurs owing to the carriage of ticks from biotopes where certain species of ticks predominate to adjacent territories where they are not otherwise found.

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